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### Note

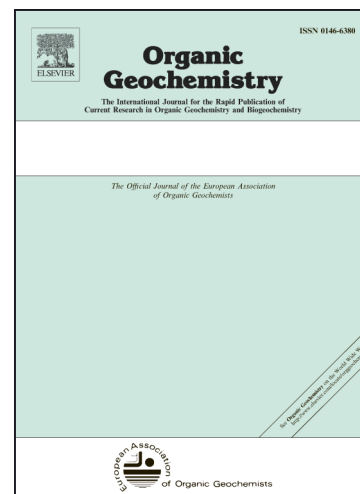
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Distributions of the Arctic sea ice biomarker proxy  $IP_{25}$  and two phytoplanktonic biomarkers in surface sediments from West Svalbard

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## ABSTRACT

The concentrations of the sea ice biomarker proxy  $IP_{25}$  (Ice Proxy with 25 carbon atoms) and two phytoplankton biomarkers (a tri-unsaturated highly branched isoprenoid (HBI) lipid (HBI III) and epi-brassicasterol) have been measured in surface sediments from West Svalbard.  $IP_{25}$  concentration exhibited a positive relationship with that of HBI III and epi-brassicasterol, suggesting that the rapidly fluctuating sea ice dynamics characteristic of West Svalbard have a similar impact on these sea ice and phytoplankton lipids, as hypothesised in earlier studies. Alternatively, the multi-year sedimentary signal may simply represent an integration of more subtle variations in biomarker distributions that reflect variability in sea ice conditions on a seasonal or annual timeframe. Our findings contrast with those reported previously for the Barents Sea, possibly due to the latter experiencing a more prominent and consistent sea ice advance/retreat cycle.

*Keywords:* Sea ice; highly branched isoprenoid; IP<sub>25</sub>; biomarker; Arctic

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## 1. Introduction

The mono-unsaturated C<sub>25</sub> highly branched isoprenoid (HBI) alkene IP<sub>25</sub> (Belt et al., 2007) represents a useful proxy for Arctic sea ice (for a review see Belt and Müller, 2013). IP<sub>25</sub> is produced by certain sea ice diatoms (*Haslea crucigeroides*, *H. spicula*, *H. kjellmanii* and *Pleurosigma stuxbergii* var *rhomboides*) that reside and bloom in the underside of seasonal sea ice (Brown et al., 2014), and is deposited in underlying sediment following ice melt in the late spring. As such, IP<sub>25</sub> is commonly found in surface sediments from regions of the Northern Hemisphere that experience seasonal sea ice cover (Müller et al., 2011; Navarro-Rodriguez et al., 2013; Stoyanova et al., 2013; Xiao et al., 2015), yet is normally undetected in year-round ice-free marine settings (e.g., Méheust et al., 2013; Navarro-Rodriguez et al., 2013). Thus far, variable sedimentary IP<sub>25</sub> concentration in downcore profiles have generally been interpreted as reflecting temporal shifts in sea ice extent (e.g., Massé et al., 2008; Müller et al., 2012), although absolute abundances exhibit a large regional variability (Stoyanova et al., 2013). Further, by co-measurement of phytoplankton biomarkers, including certain sterols, it is often possible to deduce more detailed information about sea ice conditions than through analysis of IP<sub>25</sub> alone (e.g., Müller et al., 2011). In a recent study of surface sediments from the Barents Sea, Belt et al. (2015) showed that the abundances of IP<sub>25</sub> and a further tri-unsaturated HBI (HBI III) exhibited opposing trends, with relatively high (low) IP<sub>25</sub> in regions of high (low) seasonal sea ice cover, while elevated concentrations of HBI III were

observed within the region of the retreating ice margin. Such inverse trends were also replicated reasonably well in three downcore records from the region. In contrast,  $IP_{25}$  and phytoplankton biomarker profiles in some other downcore Arctic records have exhibited parallel or 'in-phase' behaviour (e.g., Müller et al., 2012; Cabedo-Sanz and Belt, 2016) – a scenario that has thus far been interpreted as reflecting a dynamic or rapidly fluctuating sea ice setting rather than the more extreme spatial advance/retreat cycle that is an annual feature across the Barents Sea. To test this suggestion further, in the current study we measured the abundances of  $IP_{25}$ , HBI III and 24-methylcholesta-5,22E-dien-3 $\beta$ -ol (epi-brassicasterol) in surface sediments from the West Svalbard margin; a region known to experience a more dynamic and less seasonally and annually consistent cycle of sea ice conditions, at least compared to the neighbouring Barents Sea.

## 2. Experimental

Most of the current surface sediment samples (0–1 cm) have been described elsewhere (Navarro-Rodriguez et al., 2013; Belt et al., 2015) or were obtained from cores collected on-board the *James Clark Ross* (UK) during oceanographic cruises JR142 and JR211 (see Fig. 1 for locations). All surface sediment was assumed to represent modern-day accumulation. Sub-samples of freeze-dried sediment (ca. 1–2 g) were extracted via sonication in *n*-hexane, and partially purified extracts analysed for  $IP_{25}$ , HBI III and epi-brassicasterol using gas chromatography–mass spectrometry (GC-MS)

according to previously published methods (e.g., Belt et al., 2015). New biomarker concentration data are supplemented with values reported previously by Navarro-Rodriguez (2014) and Müller et al. (2011), although no HBI III data were given in the latter. All data can be found in Supplementary Table 1.

### 3. Results and discussion

IP<sub>25</sub>, HBI III and epi-brassicasterol were present in all surface sediments analysed and in similar concentration ranges (Fig. 2) to those reported previously for the region (Müller et al., 2011) and for the neighbouring Barents Sea (Belt et al., 2015). Absolute concentrations of each biomarker were quite variable, however, even for nearby locations, which may, in part, reflect the likely variability in sedimentation rates between core sites, and thus the number of years of biomarker accumulation that each surface sediment represents. Cross-plots of HBI III and epi-brassicasterol versus IP<sub>25</sub> concentrations exhibited positive relationships, although a strict linearity between them was not especially evident. Thus, linear regression analysis gave correlation coefficients ( $R^2$ ) of 0.50 and 0.48 for HBI III and epi-brassicasterol versus IP<sub>25</sub>, respectively, although the former increased to 0.88 upon removal of two possible outliers (Fig. 2d). In any case, the generally positive relationship between IP<sub>25</sub> and each of the phytoplankton biomarkers contrasts the inverted trends described

previously for surface sediments from further south and east in the Barents Sea (Belt et al., 2015).

The differences in distribution patterns between  $IP_{25}$  and the two phytoplankton biomarkers for West Svalbard compared to those identified previously for the Barents Sea likely reflect the contrasting sea ice dynamics that exist between the two regions as alluded to earlier. More specifically, the region to the west of Svalbard experiences rapid fluctuations in the position of the sea ice margin, both seasonally and annually (Fig. 1), largely due to the variable influence of the strength of the West Spitsbergen Current (WSC) that carries relatively warm water as an extension of the North Atlantic Current. Variability in the strength of the WSC and its apparent control over sea ice conditions for West Svalbard are well known for recent centuries (Vinje, 2001) and for longer timeframes inferred from biomarker-, microfossil- and mineralogical-based reconstructions (e.g., Werner et al., 2011; Müller et al., 2012), while colder Arctic waters delivered by the East Spitsbergen Current are likely to exert further influence on sea ice, especially for the more eastern sites (Fig. 1). Such dynamic sea ice conditions potentially impact in a similar manner on the production of sea ice algal ( $IP_{25}$ ) and phytoplankton (HBI III and epi-brassicasterol) lipids as suggested previously (Müller et al., 2011). On the other hand, since the sediments analysed represent several years (or decades) of accumulation, which is substantially longer than the timescales normally associated with the known fluctuations in sea ice conditions (seasonal to annual), any



contrasting behaviour that does exist between  $IP_{25}$  and phytoplankton markers for in situ sea ice conditions may not be evident within the integrated signal from a surface sediment. Such a consequence is likely to be less important for some other regions, including the Barents Sea, where the sea ice advance and retreat cycle is much more consistent on seasonal and annual timescales, at least in modern times.

## 5. Conclusions

The distribution pattern of the Arctic sea ice biomarker  $IP_{25}$  and two phytoplankton lipids (HBI III and epi-brassicasterol) in surface sediments from West Svalbard broadly reflect their general in-phase behaviour described previously in some downcore records from the area. Given the known rapidly fluctuating sea ice dynamics of the region in modern times, the observations described herein lend further support to the previous interpretations of such biomarker profiles in downcore records. The contrasting behaviours of  $IP_{25}$  and phytoplankton biomarkers in surface sediments from West Svalbard compared to those from the Barents Sea (Belt et al., 2015) may prove to be a useful consideration when interpreting further temporal trends in biomarker records for sea ice reconstruction from West Svalbard, the Barents Sea and other Arctic regions in the future.

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*Associate Editor*–Kliti Grice

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## Figure captions

**Fig. 1.** Map of the study region with locations of the surface sediments. The median sea ice extent (1981–2010) for different months (National Snow and

Ice Data Center), together with the West Spitsbergen Current (WSC) and East Spitsbergen Current (ESC) are also shown.

**Fig. 2.** (a–c): Distribution plots of  $IP_{25}$ , HBI III and epi-brassicasterol in surface sediments from West Svalbard. (d–e): Cross-plots of biomarker concentrations: (d) HBI III vs  $IP_{25}$  (circled dots indicate possible outliers); (e) epi-brassicasterol vs  $IP_{25}$ .

**Fig. 1.**

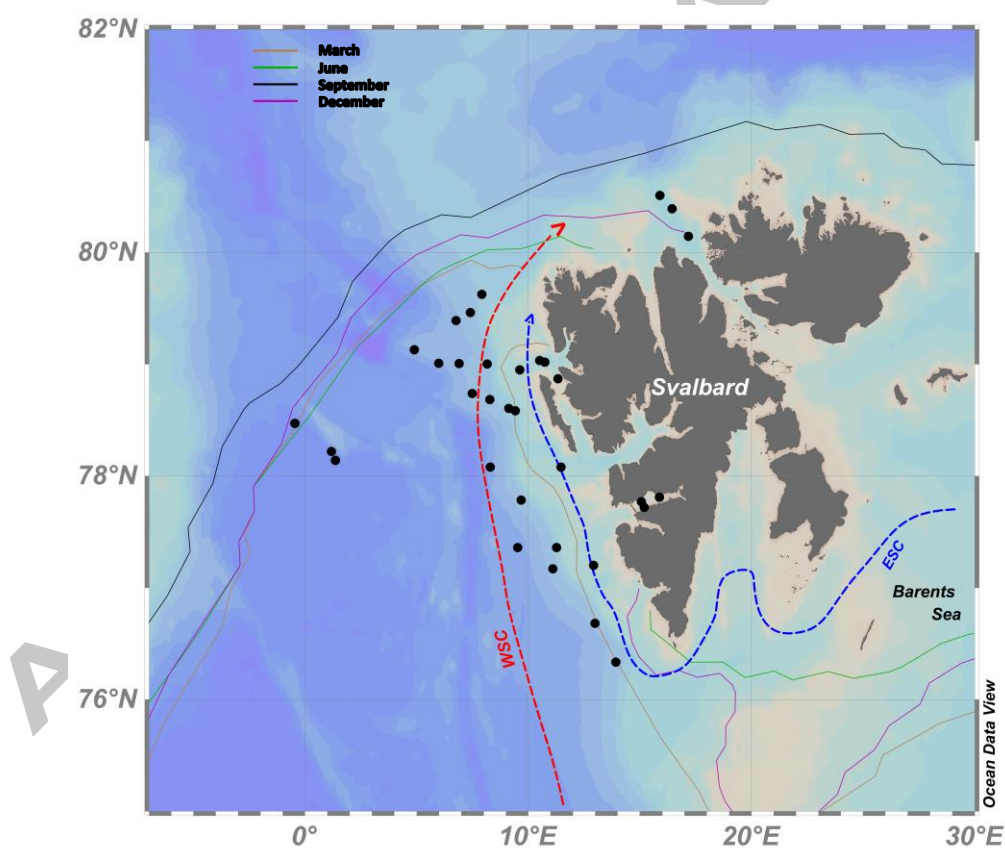


Fig.2.

